



Objective

Provide an overview of the ARSET program and training approaches relevant to water quality (WQ) monitoring, and to seek your feedback about potential training topics



Algae surrounds Toledo's intake facility on Lake Erie on August 3, 2011.

Image Credit: Driven by Climate Change, Algae Blooms Behind Ohio Water Scare Are New Normal. National Geographic.



Outline

- About the ARSET Program and Types of Trainings
- Topics for Future ARSET Water Quality Trainings
 Remote Sensing of Water Quality Parameters (Observed or Inferred Variables)
 Availability and Access of Water Quality Parameters from NASA Satellites
 Advantages and Limitations of Remote Sensing of Water Quality Parameters
- Examples of Water Quality Monitoring using NASA Remote Sensing Measurements



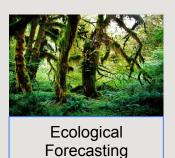
ARSET
Applied Remote Sensing Training Program

ARSET Training Areas

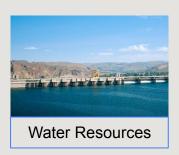
An Applied Sciences Capacity Building Program





















Agriculture

Climate

Energy

Oceans

Meteorology

ARSET Water Resources Team: Brock Blevins, Kyle Matty (UMBC), Amita Mehta (UMBC/JCET)

Tim Stough (NASA/JPL)

ARSET Program Manger: Ana Prados (UMBC/JCET)

ARSET



http://arset.gsfc.nasa.gov

Training activities for environmental professionals to increase usage of NASA observational and modeling data for decision-making support.





Online Webinars

- 1 hr a week, 4-6 weeks
- Live & recorded
- Include demos on data access

In-person Workshops

- Held in a computer lab for 2 4 days
- Focus on data access
- Locally relevant case studies

Train the Trainers

 Courses & training manuals for those interested in doing their own remote sensing trainings

ARSET Trainings

Accomplishments (2008-present)

- 66 Trainings Completed
- 4,000+ participants worldwide from:
 - 1,400+ organizations
 - 130+ countries

"I think the largest benefit to me will be just learning the basics and gaining an understanding of what products and applications are available and how I potentially use these products to help with my responsibilities as a land manager."
-Participant of a 2015 Wildfire Workshop



Participating Organizations by Country & U.S. States (2008-2015)





ARSET Trainings

Gradual Learning Approach



Basic Trainings

Webinars & Workshops Assumes no prior RS knowledge

Example: 2014 Webinar Water Quality Monitoring Using Remote Sensing Measurements

http://arset.gsfc.nasa.gov/water-resources/webinars/water-quality-monitoring-using-remote-sensing-measurements

Advanced Trainings

Webinars & Workshops Requires basic training Focuses on specific application problems and data

Example: Algal bloom monitoring in a specific body of water



ARSET ListServ

For information on upcoming courses and program updates, please sign up to the listserv

https://lists.nasa.gov/mailman/listinfo/arset



Remote Sensing of Water Quality Parameters



For Water Quality Parameters

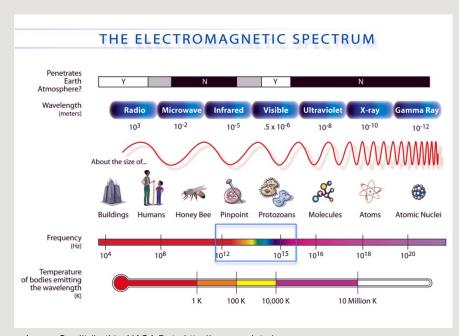
Surface water quality parameters (in red) can be obtained from NASA earth observing satellites with multiyear, near-global coverage

- Physical Properties
 - Color, Temperature, Turbidity, Suspended Sediment, Density, Heat Capacity,
- Chemical Properties
 - Salinity, Dissolved Oxygen, Conductivity, Hardness, Nutrients, pH,
- Biological Properties
 - Algal Bloom/Chlorophyll-a, Dissolved Organic Carbon, Microorganisms,

For Water Quality Parameters



Measures solar radiation reflected back to space and emitted infrared radiation



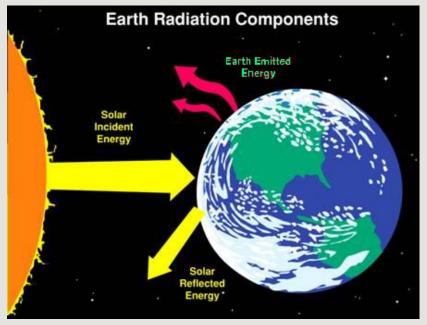
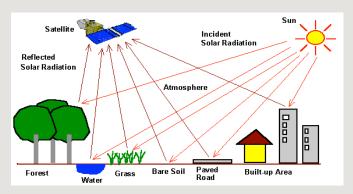
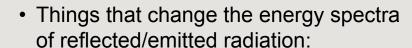


Image Credit (both): NASA Data http://mynasadata.larc.nasa.gov

For Water Quality Parameters

- Water properties are detected by measuring:
 - Reflected solar radiation
 - Emitted thermal radiation
- Every surface has its own spectral signature





- Suspended sediments
- Algae
- Dissolved Organic Matter
- Oils
- Plants
- Thermal Releases
- Most chemicals and pathogens do not have a direct impact - may be inferred from other WQ parameters



Remote Sensing Techniques

For Measuring Water Properties

- Satellite image interpretation in various spectral bands
 - Change along with changes in water quality

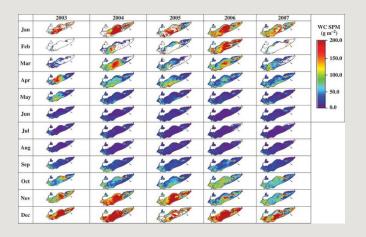


True-color MODIS image of the Great Lakes
The pale blue swirls in Lake Michigan are probably caused by a phytoplankton bloom
or calcium carbonate (chalk) from the lake's limestone floor.

Image Credit: NASA/ http://visibleearth.nasa.gov/view.php?id=68562



- Quantitative estimation using algorithms
 - Statistically relating remote sensing data and in situ measurements



Monthly mean distribution of total water column SPM (g m-2) derived from inverse modeling of MODIS L WN(748).

Credit: "Suspended particulate matter in Lake Erie derived from MODIS aquatic colour imagery." International Journal of Remote Sensing. C.E. Binding, et. al.



Availability and Access of Water Quality Parameters from NASA Satellites

For Water Quality Monitoring

- Sea-viewing Wide Field-of-view Sensor (SeaWiFS) launched in 1997 to observe ocean color
 - 1997-2010: Useful for monitoring algal presence in coastal oceans & estuaries
- Currently several satellites observe water surface properties that
 - monitor coastal oceans and estuaries
 - observe water properties of many in-land lakes
- A number of WQ parameters are operationally available from these satellites





NASA

For Water Quality Monitoring

Satellite	Sensor	Parameter
Landsat Series (7/1972 - present)	Thematic Mapper (TM)Enhanced Thematic Mapper (ETM+)Operational Land Imager (OLI)	Spectral Reflectance
Terra (12/1990-present)	Moderate Resolution Imaging Spectroradiometer (MODIS)	 Spectral Reflectance Chlorophyll-a Concentration Temperature Colored Dissolved Organic
Aqua (5/2002-present)		Matter (CDOM) Turbidity Euphotic Depth
Terra (12/1999 – present)	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)	Spectral Reflectance Temperature
National Polar Partnership (NPP) (11/2011-present)	Visible Infrared Imaging Radiometer Suite (VIIRS)	Spectral Reflectance Chlorophyll Concentration



For Water Quality Monitoring

Past	NΛ	ice	ion
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Research Missions

	Satellite	Sensor	Parameter
า	SeaStar (8/1997-12/2010)	Sea-viewing Wide Field-of-View Sensor (SeaWiFS)	 Chlorophyll-a Temperature Particulate Inorganic Carbon Particulate Organic Carbon CDOM Index
1	Earth Observing (EO-1) (11/2000-present)	HyperionAdvanced Land Imager (ALI)	Spectral Reflectance
	International Space Station (9/2009-present)	HICO	Spectral Reflectance (gathered upon request)



Water Quality Data and Access

Satellite/Sensor	Data Access Web- Tool*	Source	Coverage	Spatial Resolution
Terra and Aqua MODIS WQ Parameters	Giovanni Seadas/ Oceancolor Web	NASA Goddard Earth Sciences, Data and Information Services Center	8-day and monthly Composites 2000-present	9 km and 4 km
MODIS Level 1 and 2 Data Level 3 Data	OceanColor Web	NASA	Daily, 3-and 8 day, Monthly, Seasonal 2000-present	250 m 9 km and 4 km
NPP/VIIRS WQ Parameters	STAR	NOAA	October 2011- present	375 m
Landsat* Tm, ETM+ EO-1/Hyperion Terra/ASTER Spectral Reflectance	LandsatLook Viewer* GloVIS EarthExploer	USGS	July 1972-presnet	30 – 60 m (Landsat and EO1-) 15 m (ASTER)





Water Quality Data Access

• Giovanni: http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=ocean_month

Ocean Color SeaDAS: http://seadas.gsfc.nasa.gov

• STAR: http://www.star.nesdis.noaa.gov/sod/mecb/color/composite

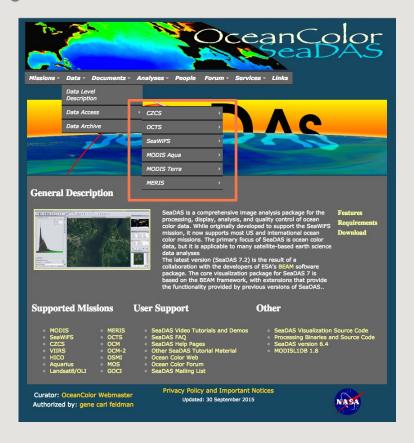
LandsatLook: http://landsatlook.usgs.gov

• GloVIS: http://glovis.usgs.gov

EarthExplorer: http://earthexplorer.usgs.gov

Water Quality Data from SeaDas

http://seadas.gsfc.nasa.gov

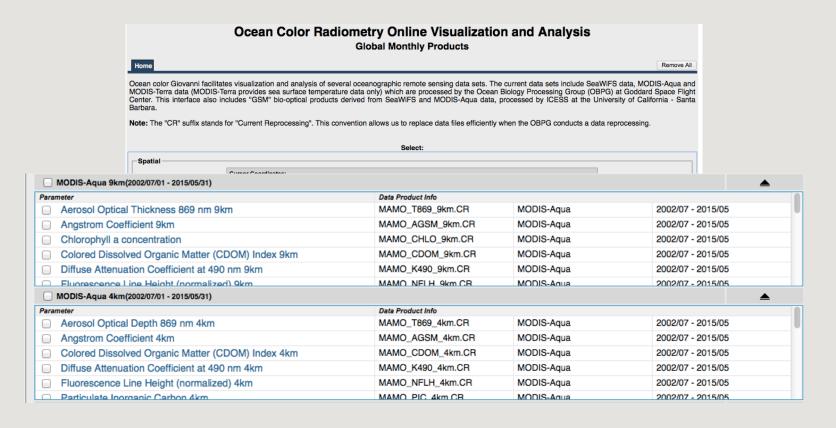








http://data1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=ocean_month





Water Quality Data and Tools

- Water Quality parameters from Terra and Aqua (MODIS), NPP (VIIRS) are available at different spatial resolutions
- Landsat (TM, EMT+, OLI), Terra (ASTER), and E0-1 (Hyperion) spectral reflectance and imagery can provide qualitative information about WQ but require further processing, in situ measurements, and algorithms to obtain quantitative parameters
- Most web-based tools have data search, spatial and temporal sub-settings, visualization, and download features

ARSET trainings provide

- Detailed descriptions of the water quality data and data access tools
- Demonstrations of data analysis and download features
- Case studies of monitoring water quality parameters over specific lakes and coastal regions



Advantages and Limitations of Remote Sensing of Water Quality Parameters



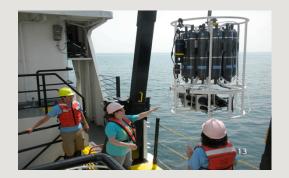
Water Quality in Situ Measurements

In situ instruments and lab analysis to monitor water quality in streams, lakes, and estuaries are conducted by:

- Environmental Protection Agency (EPA): http://water.epa.gov
- U.S. Geological Survey (USGS): http://water.usgs.gov/owq
- National Oceanic and Atmospheric Administration (NOAA): http://nerrs.noaa.gov







In Situ Measurements

Limitations

- Limited sample collection not representative of entire water body
- Periodic sample collection may not capture daily, monthly, or seasonal water quality changes
- Labor intensive and expensive

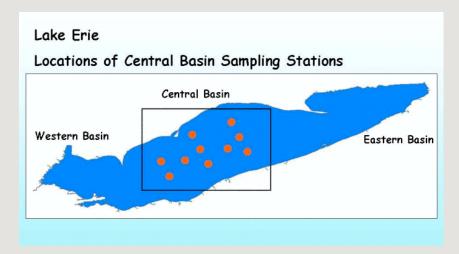


Image Credit: EPA Great Lakes Monitoring & Indicators



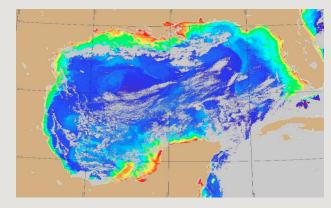
NASA

Advantages

- Provides and augments information where there's no surfaced-based measurements available
- Provides global and near-global coverage with consistent observations
- Provides continuous coverage in comparison to point measurements



Water Sampling Locations http://data.gcoos.org



MODIS Aqua satellite image from Oct. 23, 2011, showing areas of elevated chlorophyll a (in red and orange)



Remote Sensing – Measurement Characteristics

- Difficult to obtain high spectral, spatial, and temporal resolutions concurrently
- Several sensors can obtain global coverage every 1-2 days because of their wide swath width (Terra/Aqua)
- Higher spatial resolution polar orbiting satellites obtain global coverage in 8-16 days (Landsat, EO-1)
- · Large amount of data with varying formats
- Data applications generally require additional in situ measurements, processing, and algorithm development

- Spectral reflectance in the presence of clouds may be unsuitable
- Atmospheric contribution to reflectance has to be corrected to get surface water properties
- Medium-spectral band data may contain effects of multiple WQ parameters
- Data may contain land contribution near coastal zones
- Spatial resolution of data may limit usability for small water bodies



Examples of Water Quality Monitoring

Lake Atitlan Algal Bloom Monitoring 2009

NASA SERVIR Project – Courtesy of Dr. Africa Flores

Some of the threats affecting Lake Atitlan's health include:

- Unsuitable agriculture and unplanned development in Atitlan's watershed
- Lack of sewage treatment plants
- Soil erosion and agrochemical runoff into the lake



In October 2009, an algal bloom of cyanobacteria started to develop in the lake

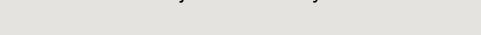
For more info:

https://servirglobal.net/Global/Articles/tabid/86/Article/867/satellite-based-lake-monitoring-in-quatemala.asp



Lake Atitlan Algal Bloom Monitoring 2009

NASA SERVIR Project – Courtesy of Dr. Africa Flores



In order to estimate the area covered by the algal bloom the red and near-infrared bands were used in the multispectral sensors:

This image portrays the algal bloom in the

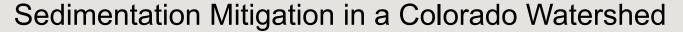
Landsat ETM+

lake in 2009

- EO-1 ALI and Hyperion
- Terra-ASTER

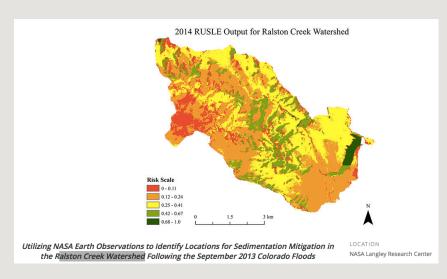








NASA DEVELOP Project - http://develop.larc.nasa.gov/



Model combined with Rainfall, Land Cover, Slope from Landsat-8 and LIDAR Measurements End User: Denver Water

 This project helped determine excessive runoff and sedimentation due to extreme rain and flooding in Denver area, and provided with a fine scale map detailing potential erosion mitigation sites

Learn more:

http://develop.larc.nasa.gov/2015/ summer_term/ ColoradoWaterResourcesII.html

Gulf of Mexico Water Quality Monitoring

NASA DEVELOP Project – http://develop.larc.nasa.gov



A Geospatial Evaluation of Drivers, Occurrences, and Distribution of Hypoxic Events within the Grijalva-Usumacinta River Delta System and the Southern Coast of the Gulf of

LOCATION

NASA Ames Research Center

Monitoring Normalized Difference Turbidity Index, chlorophyll-a (Chl) concentration, sea surface temperature (SST), colored dissolved organic matter index (CDOM), and photosynthetically available radiation (PAR)

Model combined Landsat & Aqua MODIS measurements



End Users:

Consorcio de Instituciones de Investigación Marina del Golfo de México y del Caribe (CIIMar-GoMC)

Centro del Cambio Global y la Sustentabilidad en el Sureste (CCGSS),

 Results of this project will assist local environmental and health authorities in revising water quality standards and mitigating the impacts of future Harmful Algal Bloom and hypoxic events in the region

Learn More:

http://develop.larc.nasa.gov/2015/summer_term/ GulfofMexicoWaterResourcesProject.html

Wastewater Plumes Monitoring



NASA Develop Project - http://develop.larc.nasa.gov

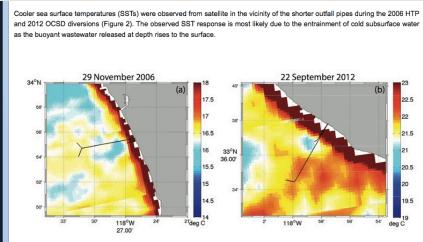


Figure 2. MODIS-Aqua SST (°C) during the (a) 2006 HTP diversion on 29 November 2006 and (b) 2012 OCSD diversion on 22 September 2012. The long and short outfall pipes are shown. Low SSTs are indicative of the plume signature and are observed in the vicinity of the short outfall pipes.

End Users:

Hyperion Treatment Plant (HTP) and Orange County Sanitation District (OSCD), Southern California

 Remote Sensing Measurements were used to detect waster water plume and impact in the southern California Bight

Sea Surface Temperature near the Outflow pipes in the Southern California Bay

Learn more:

http://podaac-www.jpl.nasa.gov/OceanEvents/2014_10_22_WastewaterDiversions

Wastewater Plumes Monitoring

NASA Develop Project – http://develop.larc.nasa.gov



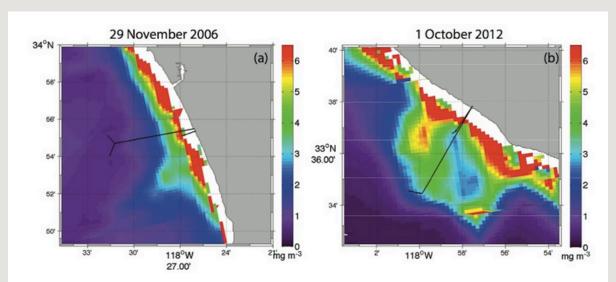


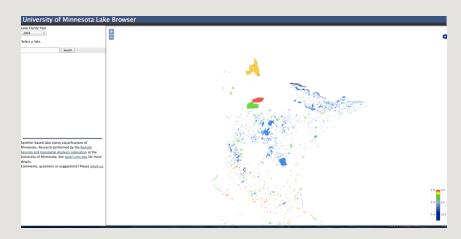
Figure 3. MODIS-Aqua chl-a (mg m⁻³) during the (a) 2006 HTP diversion on 29 November 2006 and (b) 2012 OCSD diversion on 1 October 2012. The long and short outfall pipes are shown. In (a) the wastewater plume is difficult to distinguish from adjacent waters, whereas in (b) it is denoted as decreased chl-a in the vicinity of the short outfall pipe.

Chlorophyll
Concentration
near the outflow
pipes in the
Southern
California Bight



Monitoring Lake Clarity in Minnesota Using Landsat

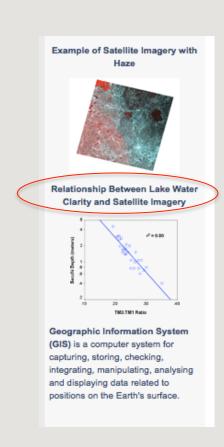
Lake Clarity Maps



More than 10,500 lakes monitored using in situ measurements and Landsat Images

Lake Clarity Maps Available for 1975, 1990, 1995, 2005, 2008

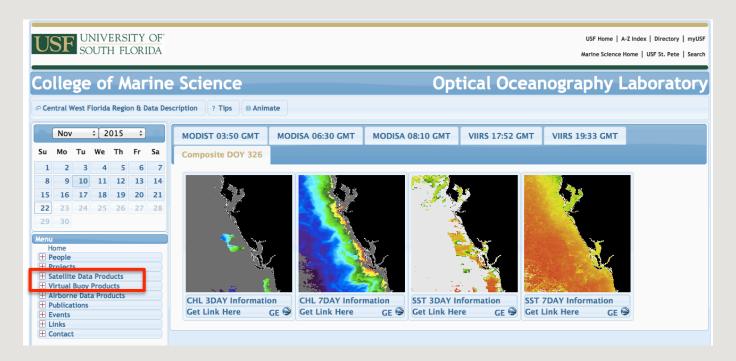
Learn more: http://water.umn.edu



Water Quality Monitoring using MODIS and VIIRS



In the Gulf of Mexico



Learn more: http://optics.marine.usf.edu/cgi-bin/optics data?roi=CWFL¤t=1

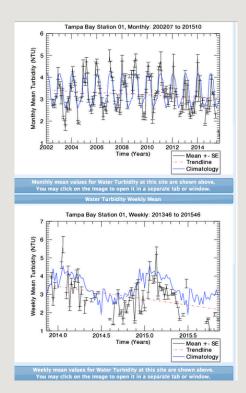
Water Quality Monitoring using MODIS and VIIRS



In the Gulf of Mexico

Satellite-derived Water Quality Data at a Surface Station



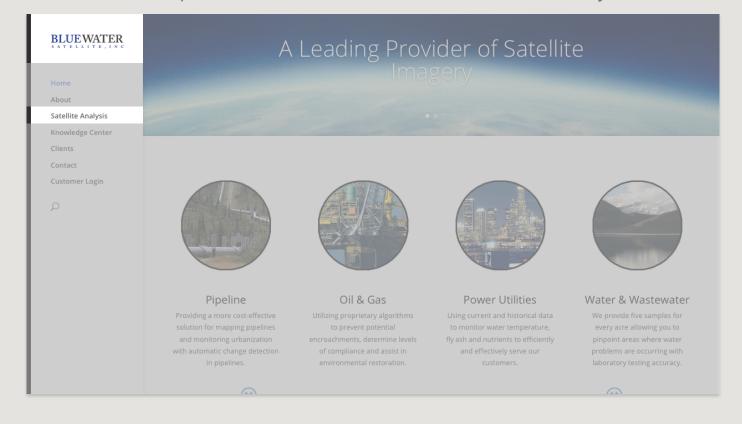


Turbidity at a station in Tampa Bay based on MODIS DATA





Blue Water Satellite - http://www.bluewatersatellite.com/satellite-analysis/



Water Quality Monitoring Using Landsat



Blue Water Satellite - http://www.bluewatersatellite.com/satellite-analysis/

Blue Water Satellite continues to develop and refine methodologies to interpret Earth imagery

Hebgen Lake

Client: PPL Montana

Problem: Increasing cyanobacteria blooms each year. Increasing number of livestock and pet deaths attributed to drinking water from the lake.

Prior testing protocol: As a condition of FERC relicensing in 2000, PPL was required to perform regular HAB monitoring. The protocol was a shoreline survey for algae blooms conducted once a week. Single-point instrument monitoring has been conducted since 2008.

Scope of Work by Blue Water Satellite:

Produce scans and datasets for cyanobacteria for five (5) dates during the summer months of 2011.

Outcome of Blue Water Satellite

Monitoring: Early detection of cyanobacteria at lower levels contributed to earlier lake warnings being posted, and ultimately to closure of the lake for recreational purposes. Satellite and in situ information about cyanobacteria and nutrient load used for decision support

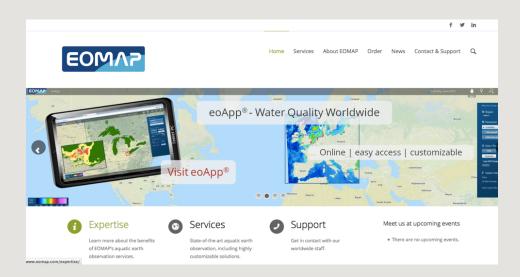
Clients of Blue Water Satellite

- BlueLeaf Environmental
- Risk Sciences Inc
- AquaTeckhnex, Inc
- · Pacific Gas and Electric



Water Quality Monitoring using Multiple Satellites **EOMAP**





- Terra/Aqua MODIS
- Landsat
- · Sentinel-2 a/b
- ENVSAT-MERIS

Learn more: http://www.eomap.com

Water Quality Monitoring Application EOAPP, EOMAP





- Maps
- Time Series of Water Quality
 Parameters for Selected Locations
- Customized Solutions Can be Requested

Learn more: http://eoapp.eomap.com/

Water Quality Monitoring EOAPP Example



Florida Lakes

Lake Apopka, Lake Harris, & Lake Griffin

Parameters:

- Turbidity
- Chlorophyll-a
- Total Suspended Matter
- Secchi Depth
- Total Organic Absorption
- Total Light Absorption

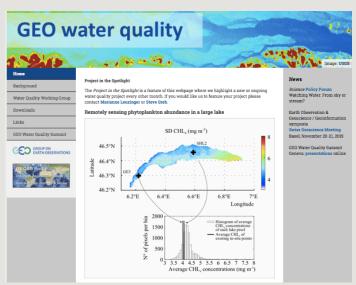
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Figure 11: Standard EOMAP 30m turbidity product from 22.04.2008, derived using Lands at 7 ETM+ satellite data (processing @ EOMAP, data @ USGS/NASA)

Group of Earth Observations (GEO) Water Quality Monitoring



Remote Sensing and In Situ Data



Spatial variability of the standard deviation of chlorophyll a (CHLa) concentrations in Lake Geneva from remote sensing data (2002 to 2012). The histogram reflects the large differences in average concentrations depending on the location of the lake. Existing insitu measurement locations (SHL2 and GE3) are not situated in regions of high chlorophyll variability.

- The majority of water quality data have been obtained through localized point measurements
- Remote Sensing measurements provide potential for dramatic expansion of available WQ data
- GEO proposes to develop an operational observing system based on remote sensing and in situ WQ data

http://www.geo-water-gualitv.org/home



Summary

- NASA satellites provide observations for monitoring several water quality parameters
- The data are easy to access through various web portals, and are freely available
- A few examples of how to apply NASA remote sensing data to water quality monitoring including algal bloom, sedimentation, waste water plume, and turbidity - were presented

- ARSET provides online and in person training on remote sensing data access, utilization, and limitations
- ARSET helps connect scientists and stakeholders seeking funding on 'research to applications' opportunities, including NASA proposals.
- ARSET is looking for your feedback on topics of interest to your community
- Trainings can be requested for your organization or region at:

http://arset.gsfc.nasa.gov/training



Thank You!

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